BIOMEDICAL ENGINEERS

OVERVIEW

Biomedical engineers use their knowledge of engineering principles and medical and biological science to improve medical instrumentation, equipment, and products; health management and care delivery systems; and medical information systems. Their work has led to important medical developments such as artificial limbs, magnetic imaging equipment, and pharmaceuticals. A minimum of a bachelor's degree in biomedical engineering, along with secondary study in another engineering discipline (such as mechanical engineering), is needed to enter the field. Approximately 20,890 biomedical engineers are employed in the United States. Job opportunities for biomedical engineers is expected to be excellent during the next decade.

THE JOB

If you have certain vision problems, you can wear disposable contact lenses to correct your vision. If you suffer from heart failure, you may be a candidate to receive an artificial heart transplant. If you recently lost a tooth, your dentist may recommend a dental implant. If you are injured during a football game, an x-ray may be ordered to rule out any fractures. As a child, you received important immunizations to guard against potentially deadly childhood diseases. What do all these situations have in common? These procedures and treatments were made possible through the work of biomedical engineers.

Biomedical engineering is a field that combines the problem-solving techniques and analytical principles of engineering with medical and biological sciences in order to help improve the diagnosis and delivery of health care.
Many biomedical engineers are involved in the research and development of medical devices that help diagnose diseases or conditions, and they develop technology that can cure, treat, or prevent diseases. Many patients owe their quality of life, if not their actual lives, to the implantation of artificial organs such as hearts, pacemakers, and cochlear implants. These devices are self supporting, and they function without a stationary power supply. Other devices currently in various stages of research and development include a bio-artificial liver and an artificial lung.

Biomedical engineers are also responsible for many devices, which, while needing continuous power supply, filtering, or chemical processing, are critically important in providing life support. An example of such a device is a dialysis machine, which improves the quality of life for people with diabetes.

Biomedical engineers also design various prostheses—artificial body parts that replace real ones. Artificial hip and knee implants help many elderly patients escape the pain caused by age or chronic diseases such as arthritis. People who have lost arms and legs due to injury or disease can increase their mobility with robotic prostheses.

Delivery of health care treatment is also improved due to the work of biomedical engineers. Tools developed by engineers range from the familiar—latex gloves, wheelchairs, tongue depressors, bedpans, and adhesive bandages—to the highly specialized, such as laser surgical tools and instruments. Think of what your next hospital procedure or doctor’s visit would be like without these items!

Some biomedical engineers specialize in the design and development of biotherapies and biotechnologies. These projects include pharmaceuticals and immunizations. Biotechnology improvements include tissue engineering in the form of artificial skin embedded in collagen, which is used for skin grafts; human-made insulin, to help regulate diabetes; and the development of laboratory-generated bone substitute, to replace human bones lost due to injury or disease.

Biomedical engineers also adapt computer software or hardware to create various health care applications. Medical imaging equipment includes 2D or 3D x-rays, magnetic resonance imaging instruments, and nuclear imaging equipment, such as positron emission tomography. These systems allow physicians to diagnose an injury or disease or to identify the location of tumors or other abnormalities. Computer applications can also help guide medical procedures such as angioplasty.

Some biomedical engineers develop computerized models to help teach students about bodily functions and systems. For example, a model of the human circulatory system is often used for teaching purposes in classrooms and museums.

Biomedical engineers do not come up with these advancements and technologies overnight. Rather, they are the result of years of research, testing, and more testing—regardless of the size or scope of the project. First the need for the application or project is identified. For example, when developing the artificial heart, the medical community expressed the need for such a device in order to lower the number of heart transplant proce-
dures, considering the demand far exceeded the supply. Working with the
design and functions of available heart-lung machines at the time, biomedical
engineers along with physicians went through several drafts of artificial
heart designs. The first few hearts were implanted in many test animals
before the first clinical trial could be conducted on a human. Throughout
the testing, approval was sought in the United States, and it was finally
granted by the Food and Drug Administration. Much additional research,
more redesigning, and more testing were done to the prototype before the
artificial heart reached the type used in surgical procedures today.
Biomedical engineers are constantly improving the design, quality, and
durability of artificial hearts due to changing research and technology.

In addition to their laboratory duties, some biomedical engineers supervise
technicians and laboratory assistants. They present their research to
the medical community, government agencies, or private companies. Some
biomedical engineers teach at the university level.

Biomedical engineers have a variety of work environments depending
on their employer. However, they typically work indoors in comfortable,
well-lit offices and laboratories. Full-time biomedical engineers typically
work 40 hours a week, but they often work longer hours as deadlines
approach or if assigned an urgent project. They often travel from laboratory
to laboratory or to meet with other specialists working on a project.

REQUIREMENTS

HIGH SCHOOL
In high school, take as many courses as possible in the life sciences, such
as biology, anatomy and physiology, and chemistry. Other useful classes
include English, mathematics, (especially algebra, advanced algebra,
geometry, trigonometry, and pre-calculus), drafting, physics, shop, computer
science, computer programming, speech, and health.

POSTSECONDARY TRAINING
You will need a minimum of a bachelor's degree in biomedical engineering,
along with secondary study in another engineering discipline (such as
electronics or mechanical engineering), to enter the field. Another option
is to earn a bachelor's degree in electrical, chemical, or mechanical engi-
neering with a specialty in biomedical engineering. Engineers who work in
research laboratories typically need a graduate degree. ABET accredits
biomedical engineering programs. Visit its website, www.abet.org, to
access a database of accredited programs in the United States.

Typical college courses include biology, physiology, biochemistry, general
physics, electronic circuits and instrumentation design, inorganic and
organic chemistry, statics and dynamics, signals and systems, biomaterials,
thermodynamics and transport phenomenon, and engineering design.
Students also take advanced science and engineering courses related to
their biomedical engineering specialty (such as bioelectronics, virtual real-
ity, or rehabilitation engineering).
IEEE Engineering in Medicine & Biology reports that many biomedical engineers go on to medical or dental school, and a few even attend law school with an end goal of working in patent and intellectual property law. Others earn a master’s degree in business administration and enter managerial positions.

**Did You Know?**

Only 20 percent of engineering degrees were awarded to women in 2015, despite the fact that they comprised 47 percent of the workforce. Yet, several engineering specialties boast a much-higher percentage of female graduates. In 2015, 49.7 percent of environmental engineering graduates were women. Other popular engineering specialties for women were biomedical (40.9 percent of graduates), biological and agricultural (34.4 percent), and chemical (32.4 percent).

Sources: American Society for Engineering Education, U.S. Department of Labor

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**Certification and Licensing**

Engineers whose work affects property, health, or life must be licensed as professional engineers. According to the U.S. Department of Labor, “this licensure generally requires a degree from an ABET-accredited engineering program, four years of relevant work experience, and completion of a state examination. Recent graduates can start the licensing process by taking the examination in two stages. The initial Fundamentals of Engineering examination can be taken upon graduation. Engineers who pass this examination commonly are called engineers in training (EITs) or engineer interns. After acquiring suitable work experience, EITs can take the second examination, called the Principles and Practice of Engineering exam.” Visit the National Council of Examiners for Engineering and Surveying website, www.ncees.org, for more information on licensure.

**Other Requirements**

Communication skills are important, since biomedical engineers often meet with other members of a design team or with other health care professionals. They must be able to explain the goals and scientific framework of their project to other engineers, technicians, medical professionals, and laypeople. At times the job is quite stressful and demanding, especially when working with an extremely complicated design or system, or when faced with tedious testing and retesting of a product. Successful biomedical engineers are calm and focused, even during the most demanding of situations. Other important traits include an analytical personality, the ability to solve problems, and scientific ability.
Cool Career: Biomedical Equipment Technologist

Students who are mechanically inclined may enjoy working in the field of biomedical equipment technology. Biomedical equipment technicians maintain and repair key medical equipment such as lasers, x-ray equipment, and machines used to perform tests such as EKGs, CT scans, and MRIs. They also modify or operate some medical instruments or equipment. Biomedical equipment technicians work in laboratories and hospitals, for medical equipment manufacturers, and for other employers that use medical equipment. They must be able to think quickly and work effectively under pressure, as they may be called to repair lifesaving equipment in time-sensitive situations. In addition to being mechanically inclined, workers in the field of biomedical equipment technology should also have good computer skills, be organized, and have excellent communication skills. Demand for biomedical equipment technicians is expected to grow about as fast as the average for all careers during the next decade, according to the U.S. Department of Labor, which reports that “employment growth will stem from both greater demand for health care services and the increasing types and complexity of the equipment these workers maintain and repair.” A minimum of an associate’s degree in biomedical technology or engineering is required to enter the field.

Contact the following organizations for more information: American Society for Healthcare Engineering (312-422-3800, ashe@aha.org, www.ashe.org), Association for the Advancement of Medical Instrumentation (703-525-4890, www.aami.org), and the Medical Equipment and Technology Association (www.mymeta.org).

EXPLORING

There are many ways to learn more about a career as a biomedical engineer. You can read books and magazines about the field, attend an after-school or summer engineering program (see www.careercornerstone.org/pcsucamps.htm for more information), and join the Technology Student Association (www-tsaweb.org), which will provide you with a chance to explore career opportunities in science, technology, engineering, and mathematics, participate in summer exploration programs at colleges and universities, and enter academic competitions. Ask your teacher or school counselor to arrange an information interview with a biomedical engineer. If you’re a college student, you can join the Biomedical Engineering Society and other organizations. Visit the websites of college biomedical engineering programs to learn about typical classes and possible career paths. Professional associations can also provide information about the field. IEEE Engineering in Medicine & Biology offers Designing a Career
Another useful resource is the American Institute for Medical and Biological Engineering's Navigating the Circuit website, www.navigate.aimbe.org.

EMPLOYERS

Approximately 20,890 biomedical engineers are employed in the United States. They work for colleges and universities, hospitals, laboratories, research facilities, pharmaceutical companies, manufacturing facilities, and government agencies.

GETTING A JOB

Many biomedical engineers obtain their first jobs as a result of contacts made through college internships, career fairs, or networking events. Others seek assistance in obtaining job leads from college career services offices, newspaper want ads, and employment and social media websites. Additionally, professional associations, such as the Biomedical Engineering Society (http://jobboard.bmes.org/jobseekers), provide job listings at their websites. See For More Information for a list of organizations. There are many opportunities available with federal agencies. Those interested in positions with the federal government should visit the U.S. Office of Personnel Management's website, www.usajobs.gov.

ADVANCEMENT

Biomedical engineers who are employed in nonacademic settings advance by receiving pay raises and supervisory duties, by working on more prestigious projects, and by receiving additional grant money to work on research projects. Those who work at colleges and universities as educators advance from the position of instructor, to assistant professor, to associate professor, and finally to professor—with an overall goal of attaining tenure. According to the U.S. Department of Labor, “tenured professors cannot be fired without just cause and due process.” Once a professor is tenured, he or she might advance by serving as department head or becoming a dean or even college president.

Some biomedical engineers use their bachelor's degree in biomedical engineering as a first step toward attending graduate or medical school and pursuing careers in law, business, medicine, dentistry, or veterinary science.

EARNINGS

Median annual salaries for biomedical engineers were $86,220 in May 2015, according to the U.S. Department of Labor (USDL). Salaries ranged from less than $51,480 to $139,520 or more. The USDL reports the following mean annual earnings for biomedical engineers by employer: scientific research and development services, $104,490; medical equipment and supplies manufacturing, $96,870; navigational, measuring, electromedical, and control
instruments manufacturing, $88,950; pharmaceutical and medicine manu-
ufacturing, $85,130; and general medical and surgical hospitals, $75,530.

Employers offer a variety of benefits, including the following: medical, dental, and life insurance; paid holidays, vacations, and sick and personal days; 401(k) plans; profit-sharing plans; retirement and pension plans; and educational-assistance programs. Self-employed workers must provide their own benefits.

EMPLOYMENT OUTLOOK

Employment for biomedical engineers is expected to be excellent during the next decade, according to the U.S. Department of Labor (USDL). The growing and aging U.S. population and demand for new medical devices and equipment is creating many opportunities for biomedical engineers. The USDL says that “smartphone technology and three-dimensional printing are examples of technology being applied to biomedical advances.” Opportunities will be particularly good in pharmaceutical manufacturing and related industries.

Interview: Sara Beck

Sara Beck is a senior mechanical design engineer at Medtronic (www.medtronic.com), a premier medical technology and services company.

Q. How long have you worked in the field? What made you want to enter this career?
A. I have worked as an engineer in the medical devices industry for more than 10 years. I entered this career because I wanted to truly impact the lives of people by using my analytical, organizational, and critical-thinking skills.

Q. What are some typical projects that you work on as a mechanical design engineer?
A. I currently support a released implantable drug pump. My primary job is to take complaints/concerns from our customers and investigate them technically. I work with a team of specialists (customer service, quality, physicians, and other engineers). As I dig into these concerns, I try to test the product in the simulated condition to understand if the device could have contributed to the issue. In the past, I have also worked on developing products such as orthopedic shoulder replacements, orthopedic instruments, a handheld device that receives heart-rate information from an internal monitoring device, and an external blood pressure measurement system. In product development, a project would consist of defining design specifications to meet customer requirements, designing a product to meet these specifications, testing the product to ensure it meets the demands, and then verifying it meets the customers’ needs. This, of course, involves working with a team of electrical engineers, system engineers, reliability/quality engineers, project managers, etc.

Q. What are some of the pros and cons of your job?
A. The best part of my job is knowing my work improves the quality of life of
many patients. The drug pump allows children with severe spasticity to walk or run by releasing a drug at the right dosage to relax their muscles; it allows people with chronic pain to enjoy active lives with their family and friends. Medtronic improves a life every three seconds. I love working for a company that cares so deeply about improving people's lives. Day to day, I enjoy working in a team to solve very complex problems.

One con of my job is that a biomedical engineer cannot design medical devices in every state, nor in every city. My husband and I are both biomedical engineers; the rest of our family lives in Ohio but there are not many job opportunities there for us.

Q. What advice would you give to young people who are considering a career in biomedical design engineering?
A. Work to obtain a co-op/internship in the field before you graduate. The University of Akron’s biomedical engineering (BME) program (which I attended) highly encouraged a one-year co-op before graduation. While it meant it would take me five years to finish my undergraduate degree, the one year of experience I gained at DePuy Orthopaedics was extremely valuable for giving me confidence that this was truly the right field for me and obtaining my first job. While the coursework ensures you can solve problems, your career the next 40 to 50 years will be slightly different day in and out than school. It's important that you experience the environment and type of work you will be doing. At minimum, make sure you can do some job shadowing.

Also, once you know what kind of products (implantables, biologicals, electrical instruments) you want to work on, focus your BME degree on what you want to do. My BME degree focused on mechanical engineering. Because of my coursework focus, co-op/internship and first job, I have the title “mechanical design engineer.”

Q. What's the future employment outlook for biomedical design engineers?
A. The medical devices industry will likely have a continued demand for engineers due to the aging population and need for better medical devices that reduce overall health care costs. In my professional opinion, there are very few medical device jobs with the title “biomedical engineer,” which is why I stress the value of a co-op/internship and solid engineering coursework.